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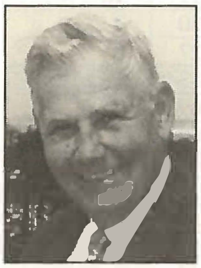

My assigned task is to talk about the importance of two communities working together. Some people may think the work of operations analysis and the development of models and simulations are indistinguishable. They are wrong, and I must take a few minutes to point out some severe distinctions between the communities. That will lead to the nature of the desirable collaboration, which is my subject. That in turn leads naturally to a central problem in academia, for which the solution is to "open doors and windows" — a term I borrow from one of NPS's four Distinguished Graduates, the estimable **Lui Pao Chuen** of Singapore.

Operations Analysis

Operations Analysis (OA) was borne in wartime with little more to work with than a sense of patriotism, slide rules, and an understanding of physics, human nature, and the scientific process. In the 1960s, a decade after the first masters degrees in OA had been awarded at the Naval Postgraduate School, two things happened. The first was a shift of emphasis, stimulated by Secretary of Defense **Robert McNamara** and his Comptroller, **Charles J. Hitch**, from operations analysis for the fleet, to systems analysis for procurement decisions in the Pentagon. Since then for 40 years the pendulum has swung back and forth between the goal of better operations and tactics and the goal of wiser decisions in Washington. The second thing was, of course, burgeoning computer power. In the use of computers there was no pendulum swing. The OA community never flagged in its zeal to apply computer power to increasingly sophisticated simulations of phenomena.

In my view, the use of computer simulations is excessive and we analysts ought to apply the same standards of cost versus effectiveness that we demand of everybody else to determine whether the rewards warrant the risks and costs. There have been some atrocious examples of costly failures in simulations. I don't bring this up to flog simulations but to point out that because there are big bucks associated with simulation *building*, we analysts slid down a slippery slope and ever so subtly came to equate model building with analysis. We forgot that our purpose is to help make better decisions. I realized what was going on when people came and asked me "what model should I use to investigate such-and-such?" The proper question is "do you know someone who can help me decide such-and-such?" An experienced analyst in the field of such-and-such problems will know how to approach the problem and what kind of model to use, which may be and often is some equations written on the back of an envelope. In any event, a vigorous effort to do some hard thinking (in the full sense of the word hard), gather some relevant data, and write some equations that describe the essential properties of such-and-such, is almost always what you do first. You may or may not want to build or adapt a complicated simulation later. Just for starters, if you find out there is no data, you can't use a simulation that requires 5,000 inputs. Without data a complicated simulation is rarely an improvement on an artful mathematical model with, say, ten parameters. Of course, the artistry is everything. That explains why the proper question is "who do you know that can help me?" If decision making is involved then computers can be a trap. An analyst who tries to substitute computer power for hard thought is only half an analyst. Computers can't substitute for artistic skill, at least not very often. Now, when you need a simulation it is because hard thinking can't substitute. I have in mind physical models like the dynamic representation of neutron flux in a reactor design. Or the configuration of genomes and chromosomes. Or complex aspects of aerodynamics or warship hydrodynamics. Or the configuration of the facilities in a bridge or combat center. Or the design of the first manned satellite.

The point is that 95% of all decisions can be improved, and much fundamental knowledge can be extended, without resort to a simulation.

Operations analysis is applied science. A lot of academic work is in basic research which tries to find general propositions, widely applicable. It took me about five years to work out the salvo equations and another five to write them up because nobody was paying me to develop this fundamental variation from Lanchester equations. I also spent a lot of time looking for a fatal flaw, because the message of the salvo equations is bad news for an all-big-ship fleet.

I regard building complicated simulations, ours, yours, the Applied Physics Lab's, Cal Tech's, or anyone else's as general research. Why? Because they cost a lot of money and so if they aren't widely applicable they aren't worth it. Therefore when I make the point that the analysis community and the modeling and simulation communities need to talk to each other I mean that we have a few, vital areas for intense collaboration. A Venn diagram would show a five or ten percent overlap.

Modeling and Simulation

So much for the point of view that analysis and modeling are indistinguishable.

The operations research community popularized models as descriptors of phenomena, but modeling now extends far beyond the boundaries of operations research. Dynamic representations of phenomena are found throughout science, engineering, finance, transportation, and medicine — it is hard to find a community that does not apply them, and it is a bold analyst who would still claim proprietorship over them. A measure of OR's success is the extent to which models and simulations have infiltrated the world.

Modeling (creating representations of) intricate scientific phenomena has expanded far beyond both the military and commercial operations research communities. Our child has grown up. He has his own skills and culture and purposes. We must let him find his own way to develop sophisticated simulations of, say, virtual environments, genetic algorithms, and representations that illuminate the theories of complexity and chaos.

Taxonomies differ, but my own, adopted by the Military Operations Research Society (MORS), uses "model" as the umbrella term, under which are mathematical representations (analytical models), computer simulations with no man in the loop, war games with human participants, and field exercises in which humans use actual equipment extensively. There are also hybrids in which a few real pieces of equipment are combined with simulated representations all netted together. Other lists can be found in the three editions of *Military Modeling for Decision Making* published by MORS. These help a comprehensive understanding of the modeling community, but here I simply want it understood that even for military purposes models and simulations are like the elephant and the blind men who describe a different beast depending on which limb they touch.

Then there are *simulators* used for training or testing or entertainment. Simulators must involve a human participant and so are neither a military simulation operated without human involvement or a "war game" except in a bastardized sense. With simulators we are getting very close to the domain of Naval Postgraduate School's popular MOVES Center for the development and construction of artificial environments into which human subjects are placed for any of the above purposes.

Next we have come to the most important connection between analysis and modeling. I use a simple illustration from personal experience. By the mid-1970s I had about ten years of practical experience in military OR. I knew a lot about modeling and experimentation for investigative purposes-for improving tactics and developing better fighting machines. Then I became the Chief of Naval Education and Training Support (CNET SUPPORT). I learned my ignorance of the vast use of models for training. I had seen a big Fleet ASW (Anti Submarine Warfare) trainer used to teach hunter-killer tactics and tried war gaming on the huge Naval Electronic Warfare Simulator at the Naval War College. But as CNET SUPPORT, I became responsible for the development and operation of the Navy's family of aircraft simulators that taught pilots how to fly. Aircraft simulators were everywhere, they were expensive, they did miraculous things, and their application was very controversial! Incidentally, they still are all of those things. I just signed forward a research proposal by one of our operations analysts in human factors, **Mike McCauley**, to do experimentation with Army helicopters at Fort Rucker.

In the 1970s it was dawning on folks that the objective of simulator fidelity-of motion and visual cues-had been taken to ridiculous extremes. There was a TA-4 simulator which the developer claimed did not just emulate the handling and aerodynamics of TA-4 aircraft in general. He said it duplicated the performance of one particular, actual TA-4, and he could tell you its side number! When operations analysts—whom we called education specialists—tested learning effectiveness they found that motion had little or no value, yet some trainers had been built at great expense with six degrees of motion. They also found out how much visual detail with computer graphics was enough to teach landings and nap-of-the-earth flying. For night carrier landing practice nothing but the carrier deck lights-little pinpoints on a black background-are needed to give a fighter pilot sweaty palms in the simulator's cockpit. All of us here know that graphical representation can be pretty sketchy when the aircraft is traveling at several hundred knots, but in the 1970s that truth was just trickling over from the operations analysts to officer aviators in the Naval Air Systems Command, which wrote the specs and paid the bills.

These are the things that the computer software designer does not know how to test and why operations analysis are indispensable. They were true then, and they are still true today.

Opening the Doors

Now we come to my deeper message and the notion of "opening doors." P. C. Lui, the Chief Defence Scientist in his Ministry of Defence and adjunct professor at the University of Singapore, coined the phrase to explain that collaboration is more like creating doors in a house than the hackneyed analogy of "eliminating stovepipes." To eliminate stovepipes is to create a one-room house. It is an invitation to chaos. Cutting doors in walls allows communication to take place without the loss of privacy and quiet for contemplation. Let me stretch the analogy a bit further. Consider education in a one-room schoolhouse. To teach eight grades in one room you had to be organized, you had to maintain discipline, and you had to have the knowledge of a Renaissance Man. One such renaissance man, by the way, was my mother, who drove her own horse and buggy from home to teach in her one-room school.

A university is not very good at opening doors. Traditional disciplines organized in departments are the rooms in a university, and few departments know how to open communications to pursue cross-discipline studies. Professors teach their disciplines and explore their well-defined domains in depth. They feel they must be soloists in order to stay current with the advances in their disciplines. To an extent they are right. Even in a department as well-defined as computer science, a university faculty does not know how a graduate will apply the education. He may work many places and do many quite different things. One, but only one, of those applications is a career in building computer models and simulations.

But the Navy is interested in military domains like undersea, surface, and air warfare, or like operational logistics and information operations. At NPS we deal with this problem in part by creating departments that encompass military domains. For instance they teach operational logistics in the Operations Research Department and their models apply to logistics problems. Information warfare is taught in the Information Sciences Depart-

(See **WORKING TOGETHER,** *p. 33)*

foundly capitalizes on distributed, networked effects. Advantage can emerge from a broad pool of inputs and manifest itself in a multitude of ways, each of which will likely not be evident to an opponent until advantage is ready to be applied. A primary source of advantage in distributed, networked coalition forces, arises from networked effects distributed in many dimensions throughout a force that can be summoned for use in the manner dictated by evolving conditions.

There are many impediments to the vision of NCO, including economic, cultural, doctrinal, and technical factors, along with the risk of introducing new vulnerabilities. These factors act as both constraints and challenges, limiting and shaping the networked force configurations and concepts of operation that can practically be realized. In a coalition force, the same constraints apply, often for intractable reasons rooted in sovereignty issues. It is generally recognized that the complexity of the netted force will demand a co-evolution of systems, technology and doctrine. Force experimentation has been adopted as the co-evolution mechanism. However, it is not feasible to explore the requisite paths by experimentation alone; attempts to do so yield heuristics that create a risk of misunderstanding the gap between experiment-observed and battlespace-realized capability. Appropriate analytical methods need to be applied to explore adequately the problem space in a timely, tractable and affordable manner.

- *WG 6: Applying NCO to an Actual Event.* This working group will examine the application of Network Centric Operations in support of recent operations in Afghanistan and Iraq. Some potential topics include collaborative targets, what length of time is "critical," how quick-turnaround analyses support the event, what type(s) of analysis(es) is(are) recommended, and the different ways that operations analysis and lessons learned were used to reduce time for time critical strikes. Additionally, if possible, the working group plans to look at the data for Operations Desert Storm and Iraqi Freedom, such as the percentage of aircraft that took off without defined targets and how many of these actually hit "good" targets. The participants will look for the limiting factors, the tools and techniques, and the different ways that operations analysis can help take information and enable events.

Attendance

Attendance is limited to 200 people – or about thirty participants per working group. If you are interested in attending the mini-symposium to ascertain the state of the practice, and/or participating in the workshop by "rolling up your sleeves" and making a contribution, please go to the MORS web-site at http://www. mors.org and click on the "Operations Analysis Support for Network Centric Operations" link or call the MORS Office (703-933-9070) to request an application.

If you have any questions, please feel free to contact the Workshop Staff below. ✪

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WORKING TOGETHER
(continued from p. 9)

ment, sometimes with models that represent networks. A harder problem is to move from mathematical knowledge to physics to mechanical and civil engineering, or in the Navy's case to marine and space engineering, using models for ship design and satellite deployment.

NPS research also serves the Navy and DoD. Key components are three research institutes. They open doors across campus to foster interdisciplinary studies. The Wayne Meyer Institute of Engineering and Analysis is in its fourth year-long project. It incorporates the work of as many as 15 faculty and 80 students and several departments. A typical project involves space engineering, operational logistics, warship design, information operations, mission analysis, and future tactics. This takes more than systems engineering. This is the design of a system of systems. Models and simulations are vital contributors to the projects but they are many and varied. The project is as close to working in one room—having no stovepipes—as one is likely to get. Do I need to tell you this highly integrative thinking is hard to do? But it is ideal education for officers who will do the same kind of systems thinking for the rest of their military lives.

I have indicated very briefly the domain of 21st Century military operations analysis. Almost from the beginning OA has modeled and simulated the dynamics of warfare, but its models must be subordinate to the purpose of operations analysis, which is to help make better operational and programmatic decisions. Second, I have indicated the expanded breadth of the modeling and simulation community. It is our child but its applications are now ubiquitous and extend far beyond our domain. Finally, I have offered that both communities must be allowed to work in their own rooms but they must keep the door open between them and stay connected. ✪